

**Progress Report, DOE Grant #DE-FG03-97ER62360  
July 17, 2000**

**Michael R. Poellot, Principal Investigator**

**Analysis of In Situ Cloud Microphysical Measurements  
for the ARM Remote Cloud Sensing IOP**

**Scientific Goals**

This report presents the progress and accomplishments of the University of North Dakota (UND) in the analysis of ARM in situ microphysical data, for the period 1 July 1999 to 30 June 2000. Since a continuation of this grant was received in January 2000, this period includes both work done toward completing the original grant objectives and tasks under the continuation.

Under the original grant, analysis objectives were to

- (1) characterize microphysical properties of the non-anvil cirrus clouds sampled during the RCS IOP;
- (2) analyze the microphysical properties of thunderstorm anvil clouds sampled during the IOP and compare them with the non-anvil cirrus; and
- (3) participate in collaborative studies with other ARM science team members.

The goals of work under the continuation are to

- (1) participate in case study analyses of ARM IOP cloud data;
- (2) Collaborate with other ARM investigators in comparisons of in situ and remote sensing observations and collaborate in radiative transfer model sensitivity testing; and
- (3) Develop and provide value-added products to the ARM data archive for further use by ARM investigators.

**Accomplishments**

- In situ microphysical measurements from three thunderstorm cirrus anvils have been analyzed to better understand the particle size distributions, ice water contents and ice crystal habits of these clouds.
- Software for the derivation of cirrus cloud ice water content from in situ measurements is being refined and tested.
- Software to convert UND Citation data into NetCDF format is under development.
- Collaborative analysis of Citation data is ongoing to assist in the interpretation of cloud remote sensing observations and the modeling of cirrus cloud properties.

## **Progress and Accomplishments**

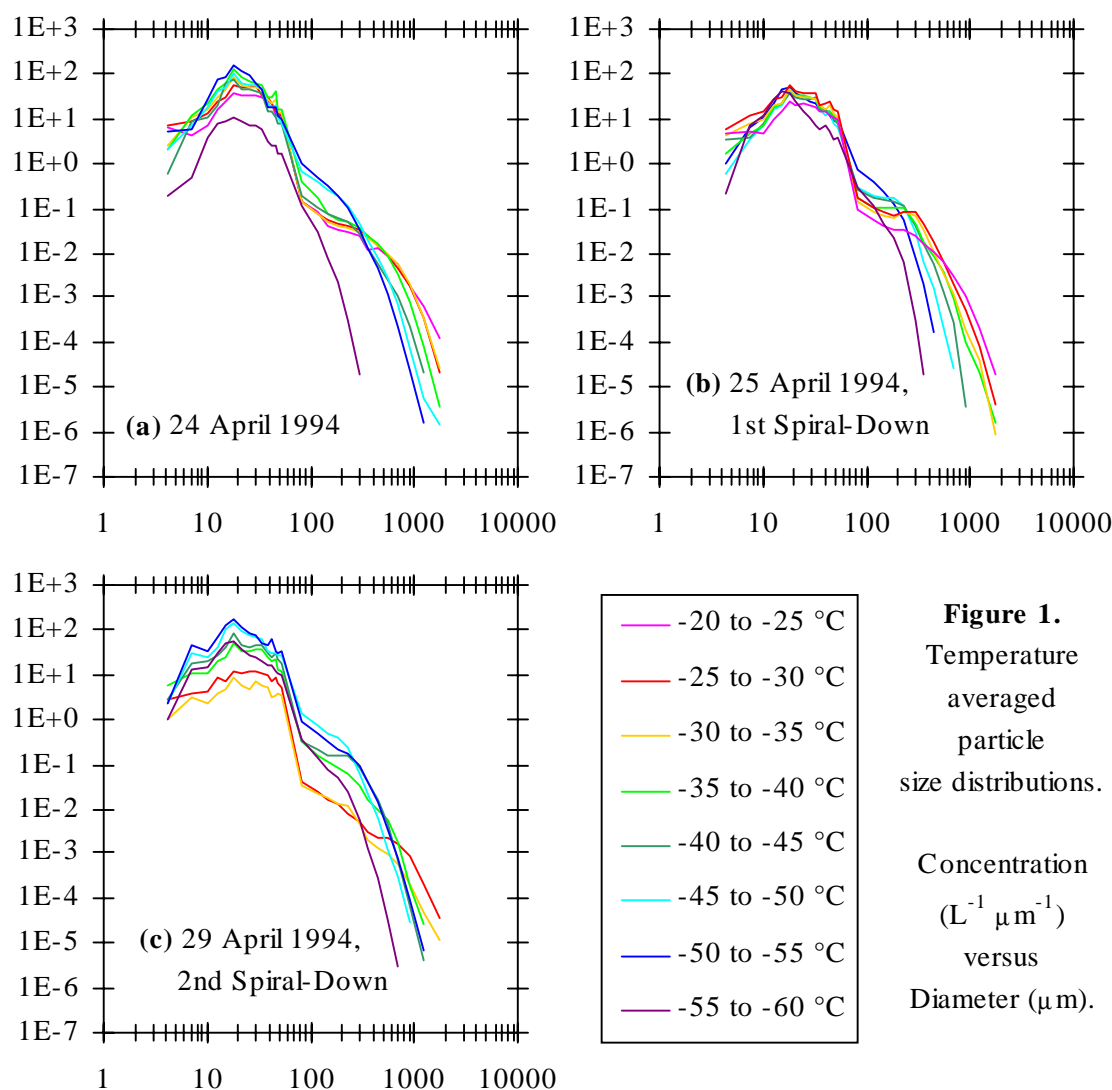
### The Microphysical Structure of Aged, Mid-Latitude, Continental Anvil Cirrus: Three Cases from ARM 1994

(from Hilburn, Poellot and Arnott, submitted to *Journal of Applied Meteorology*)

Three anvils sampled as part of ARM 1994 allowed us to document the structure of aged, mid-latitude, continental anvil cirrus. The average 2D-C IWC and 2D-C concentration in anvils sampled from 50 to 400 km downwind ranged over an order of magnitude, and the larger scale structure of the April 25<sup>th</sup> anvil seemed to display a pulsing character. Particle size distributions contained similar features on all three days such as a mode near 20  $\mu\text{m}$  and a plateau in the 100 to 300  $\mu\text{m}$  region. Figure 1 shows the particle size distributions for the 24<sup>th</sup>, 25<sup>th</sup> (1<sup>st</sup> spiral-down) and 29<sup>th</sup> (2<sup>nd</sup> spiral-down) averaged over 5°C layers. Spectra on all three days exhibit the general trend of fewer small particles and more large particles with increasing temperature. This trend is consistent with sedimentation and with aggregation. Plate polycrystals were the predominant habit in the anvil sampled on the 24<sup>th</sup> and 25<sup>th</sup>, but monocrystals were also prevalent in the anvil sampled on the 29<sup>th</sup>.

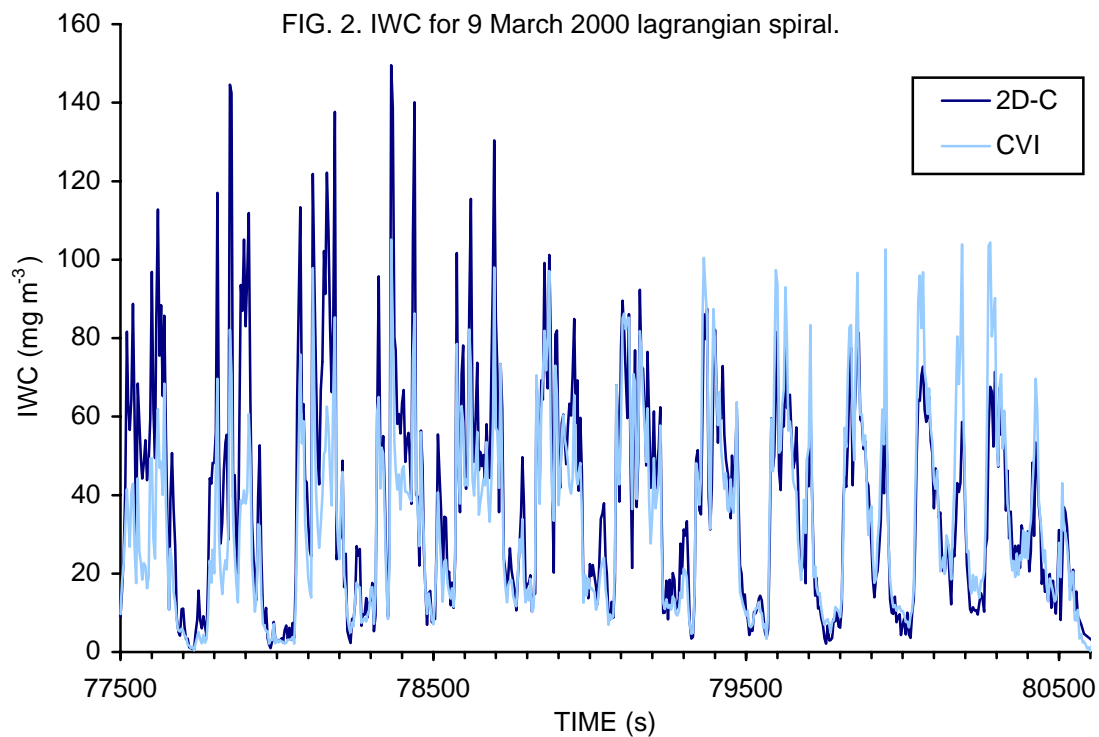
### Derivation of ice water content

One of the properties of cirrus clouds that affects the transfer of radiation and the remote sensing of cloud properties is the cloud ice water content (IWC). Unfortunately, most in situ measurements of cirrus have been in terms of habit, size and number concentration, not ice mass. Thus, IWC must be derived through the use of relationships prescribing mass as a function of particle size and habit as determined from particle image data. UND is in the process of refining an algorithm (Heymsfield and Parrish 1979) to accomplish this and we will be processing the Citation 2D-C probe microphysical data to add this product to the ARM data archive.



Fortunately, direct measurements of IWC were made in the Spring 2000 IOP through use of a counter-flow virtual impactor (CVI). This instrument has a lower cut threshold of approximately  $9 \mu m$ , compared with the 2D-C limit of approximately  $66 \mu m$ . As a test of the modified Heymsfield and Parrish IWC algorithm, data from the decent spiral portion of the 9 March 2000 flight were chosen. Nearly all crystals in this cloud were bullet rosettes, as indicated by the 2D images and verified by real-time observation of the Cloud Particle Imager (CPI) display (resolution of  $2.3 \mu m$ ). A comparison of IWC is shown in Figure 2. The

agreement is quite striking, although the 2D overestimates IWC at the start of the spiral in the upper portion of the cloud. This is not what would be expected, considering the top of the cloud contains more small crystals that would be captured by the CVI but missed by the 2D-C. A modified version of the Brown and Francis M-D coefficients was derived from this data set.



#### Conversion of Citation Archive Data to NetCDF Format

To make the Citation archive data more accessible to the ARM community, software is being developed to convert much of these data into NetCDF format. These files will include metadata describing the data parameters. Once this software is fully implemented, data from all Citation IOPs will be processed and placed into the ARM archive.

## Collaborations

A number of collaborative efforts have also been completed or are currently in progress. In situ sampling of cloud droplets by the Citation in Oklahoma in 1997 are used to evaluate a ground-based remote-sensing technique for retrieving profiles of cloud liquid-water content (Frisch et al. 2000. Submitted to JGR). A response to reviewers' comments is being prepared. Aerosol measurements made by the Citation were used as part of a study of the smoke associated with the 1998 Central American fires (Peppler et al 2000. Submitted to BAMS). We have also worked with Ivanova, Mitchell, and Arnott from DRI in the interpretation of FSSP data for parameterizing bimodal size spectra for mid-latitude cirrus. Finally, a case study analysis of data from May 8, 1998, is underway, including collaboration with investigators from DRI, Utah, and NASA Goddard.

## References

Heymsfield, A. J., and J. Parrish, 1979: Techniques employed in the processing of particle size spectra and state parameter data obtained with the T-28 aircraft platform. NCAR/TN-137+1A, National Center for Atmospheric Research, Boulder, CO, 89pp.

Brown, P. R. A., and P. N. Francis, 1995: Improved measurements of the ice water content in cirrus using a total-water probe. *J. Atmos. Oceanic. Technol.*, **12**, 410-414.

## **Refereed Publications**

Frisch, A. S., B. E. Martner, I. Djalalova, and M. R. Poellot: Comparison of radar/radiometer retrievals of stratus cloud liquid water content profiles with in situ measurements by aircraft. Submitted to *J. Geophys. Res.*, 1999.

Hilburn, K. A., M. R. Poellot, and W. P. Arnott: The microphysical structure of aged, mid-latitude, continental anvil cirrus: Three cases from ARM 1994. Submitted to *J. Appl. Meteor.*, 2000. [copies sent with this report]

Peppler, R. A., C. P. Bahrman, J. C. Barnard, J. R. Campbell, M. D. Cheng, R. A. Ferrare, R. N. Halthore, L. A. Heilman, D. L. Hlavka, N. S. Laulainen, C. J. Lin, J. A. Ogren, M. R. Poellot, L. A. Remer, K. Sassen, J. D. Spinhirne, M. E. Splitt, and D. D. Turner: ARM Southern Great Plains Site observations of the smoke pall associated with the 1998 Central American fires. Submitted to *Bull. Amer. Meteor. Soc.*, 1999.

## **Extended Abstracts**

Frisch, A. S., G. Feingold, I. Djalalova, and M. R. Poellot, 2000: On the retrieval of the effective radius in continental stratus clouds with cloud radars. *Proceedings of the Tenth ARM Science Team Meeting*, San Antonio, March 13-17.

Hilburn, K. A., M. R. Poellot, and W. P. Arnott, 2000: The microphysical structure of anvil cirrus: Three cases from ARM 1994. *Proceedings of the Tenth ARM Science Team Meeting*, San Antonio, March 13-17. [copies sent with this report]

Ivanova, D., D. L. Mitchell, W. P. Arnott, and M. R. Poellot, 2000: Parameterizing bimodal size spectra for mid-latitude cirrus. *Proceedings of the Tenth ARM Science Team Meeting*, San Antonio, March 13-17.

## **Status of Submitted Refereed Publications**

Frisch, et al. (JGR) – responding to reviewers' comments.

Peppler, et al. (BAMS) – response to reviewers' comments has been submitted.